So, downtime cost per hour equal to 3% of your equipment cost. Equipment cost is nothing but 900 rupees per hour.

$$\textbf{Downtime cost per hour} = \frac{3}{100} \times (900) = 27 \textbf{ rupees per hour}$$

your machine is going to operate in a year for 2000 hours. So, what is your yearly downtime cost? Yearly downtime costs for the first year is,

$$\textbf{Downtime cost per year} = 27 \times 2000 = 54{,}000 \textbf{ rupees}$$

This is your per year, per year in the sense for the first year, 54,000 rupees for the first year is your downtime cost. Similarly, calculate the downtime costs, let us calculate for the second year, in the second year the downtime percentage is 6%. So, downtime cost is 6% of your equipment cost, equipment cost is 900 rupees per hour.

$$\textbf{Downtime cost per hour} = \frac{6}{100} \times (900) = 54 \textbf{ rupees per hour}$$

$$\textbf{Downtime cost per year} = 54 \times 2000 = 1{,}08{,}000 \textbf{ rupees}$$

So, 1,08,000 rupees is your downtime costs for the second year. Similarly, you calculate a downtime cost for all the years for the entire life of the machine. Now, you find the cumulative down time cost. Everything is done on cumulative basis. So, find the cumulative downtime cost by adding it.

So, 54,000 + 1,080,00 gives you 1,62,000, 1,62,000 + 1,62,000 gives you 3,24,000 for the third year, So, like that you keep on adding it you will get the cumulative cost. So, now, you know the cumulative usage, every year it is going to be 2000 hours, add it. Now the cumulative cost per hour you can calculate by dividing the 6th column by the 7th column values

$$\textbf{Cumulative cost, end of the first year} = \frac{54{,}000}{2000} = 27 \textbf{ rupees per hour}$$

That will give you the cumulative downtime cost per hour as 27 per hour for the first year. Similarly, for a second year, it is

$$\textbf{Cumulative cost, end of the second year} = \frac{1{,}08{,}000}{4000} = 40.5 \textbf{ rupees per hour}$$

So, like that you calculate these values for all the years. We are just going to divide the 6th column with the 7th column value you will get this the cumulative cost per hour.

Now, you have to account for the loss in productivity. So, the loss in productivity is also going to result in increase in the downtime cost of the machine. So, as we discussed earlier the loss of productivity results in increase in production cost because the machine has spent the time in the repair yard. So, after the service when it comes back to the project site we will be behind the project schedule. So, to bring the productivity back to the original production rate we need to engage the machine for more number of operating hours or we need to even increase the number of machines or we need to increase the number of workers.

So, to bring back the productivity to the original production rate. So, for that we have to increase, we have to spend some more cost, some more money we have to spend. So, that results in some increase in cost due to downtime. So, that is what is called as productivity adjusted cumulative downtime costs per hour that is what we are going to find here. Productivity adjusted cumulative cost per hour we are going to find that.

So, you know that the productivity factor is given as the input data in this problem. So, for the first year there is no change at all, but for the second year there is loss in productivity, 0.98. So, I want to say 40.5 is my cost per hour, the productivity corresponding is 0.98, to bring back this productivity to 1, I need to spend some additional cost,

$$\textbf{Productivity adjusted cumulative cost, first year} = \frac{40.5}{0.98} = \textbf{41.33 rupees per hour}$$

So, this is an increase in cost I am facing due to the downtime to bring back my productivity to the original production rate, I need to spend some more efforts on cost. So, that is what is productivity adjusted downtime cost, so you are going to find that by dividing this 8th column by 9th column, you will get this,

$$\textbf{Productivity adjusted cumulative cost, second year} = \frac{54}{0.97} = \textbf{55.67 rupees per hour}$$

$$\textbf{Productivity adjusted cumulative cost, third year} = \frac{65.25}{0.95} = \textbf{68.68 rupees per hour}$$

So, this gives you productivity adjusted cumulative cost per hour. So, we have calculated it downtime cost. So, let us now move on to the next cost, which is nothing but your obsolescence cost.

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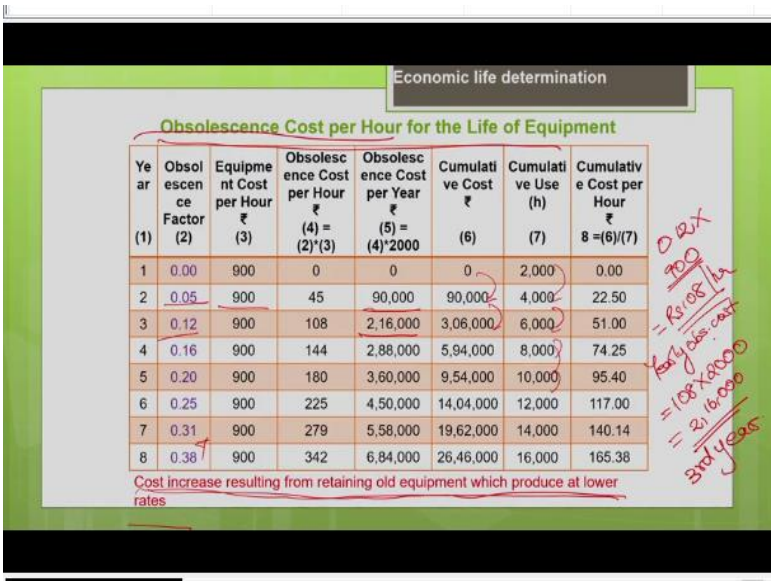


| Year (1) | Obsolescence Factor (2) | Equipment Cost per Hour ₹ (3) | Obsolescence Cost per Hour ₹ (4) = (2)*(3) | Obsolescence Cost per Year ₹ (5) = (4)*2000 | Cumulative Cost ₹ (6) | Cumulative Use (h) (7) | Cumulative Cost per Hour ₹ 8 =(6)/(7) |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 900 | 0 | 0 | 0 | 2,000 | 0.00 |
| 2 | 0.05 | 900 | 45 | 90,000 | 90,000 | 4,000 | 22.50 |
| 3 | 0.12 | 900 | 108 | 2,16,000 | 3,06,000 | 6,000 | 51.00 |
| 4 | 0.16 | 900 | 144 | 2,88,000 | 5,94,000 | 8,000 | 74.25 |
| 5 | 0.20 | 900 | 180 | 3,60,000 | 9,54,000 | 10,000 | 95.40 |
| 6 | 0.25 | 900 | 225 | 4,50,000 | 14,04,000 | 12,000 | 117.00 |
| 7 | 0.31 | 900 | 279 | 5,58,000 | 19,62,000 | 14,000 | 140.14 |
| 8 | 0.38 | 900 | 342 | 6,84,000 | 26,46,000 | 16,000 | 165.38 |

So, every year your obsolescence factor is increasing as machine is becoming more obsolete. So here we are trying to calculate the cost increased resulting from retaining the old machine with us, which is producing at a lower productivity rate. So, your machine is being subjected to wear and tear as the age of machine is increasing. So, because of that there will be some loss of productivity of the machine, there will be increasing maintenance and repair costs associated with the machine.

But there may be many competitive models in the market available with a better productivity at a lower cost and even with better advanced technological features. So, instead of switching over to the new machine as we are just clinging on to the old machine what is the increasing cost we are facing that is what is the obsolescence cost, that is what we are calculating now. Costs increased resulting from retaining the old equipment which produces lower rate.

So, that is what we are going to calculate here. So, this obsolescence factor is also calculated as a percentage of a equipment cost. Equipment costs you know, approximately 900 rupees per hour we are going to use a value here. So, calculate obsolescence cost for every year, first year obsolescence is 0. So, let us calculate it for second year it is nothing but obsolescence factors is

**Obsolescence cost per hour = 0.05 × 900 = 45 rupees**

So, this is hourly basis. Now, you have to calculate for the entire year. So, yearly obsolescence costs for the second year

**Obsolescence cost per second year = 45 × 2000 = 90,000 rupees**

Now, similarly, calculate the obsolescence cost for the second year. The obsolescence factor is 0.12

**Obsolescence cost per hour = 0.12 × 900 = 108 rupees**

This is your obsolescence cost. Your equipment cost is 900 per hour, but your obsolescence cost is 108 per hour. Now find the yearly obsolescence cost yearly obsolescence cost is

**Obsolescence cost per third year = 108 × 2000 = 2,16,000rupees**

This is for the third year. Now, you find the cumulative obsolescence cost. You add it you will get the cumulative obsolescence cost for every year. You know the cumulative usages for every year it is 2000 hours. So, you can add it. Now similarly, you find the cumulative cost per hour. So, the cumulative cost per hour is going to be nothing but column 6 divided by column 7, as we did for the earlier cost, the same methodology we are going to follow here.

$$\textbf{Obsolescence cumulative cost in second year} = \frac{90{,}000}{4000} = \textbf{22.50 rupees per hour}$$

Similarly, for the third year, it is nothing,

$$\textbf{Obsolescence cumulative cost in third year} = \frac{3{,}16{,}000}{6000} = \textbf{51 rupees per hour}$$

If you are going to hold your machine with you for 3 years, your obsolescence cost per hour for 3 years will be 51 rupees. So, that is what you mean on cumulative basis. So, the same way you calculate the cumulative cost per hour for the entire life of the machine. So, you can see that the obsolescence cost is increasing with the time. Similarly, your downtime cost also the table you can see it is increasing with the time increasing with the age of the machine. Now, let us summarize all the costs we have calculated so far.

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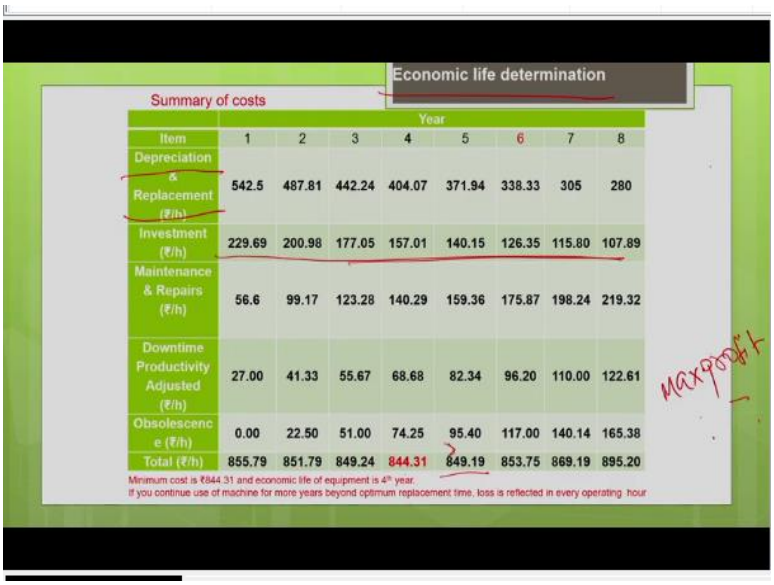


So, that we can estimate what is the optimum replacement type of the machine or what is the economic life of the machine? So, the first is depreciation of the replacement cost. So, I have just summarized the values we have estimated for the 8 years. Similarly, the investment cost, similarly the maintenance and repair cost for all the 8 years, downtime cost for all the 8 years, then the obsolescence costs for all the 8 years. So, one thing to note here is your depreciation cost it is decreasing, with the age of machine.

Investment cost is also decreasing with the age of machines, as the investment cost is getting distributed over a greater life, greater usage, your cost is getting reduced per hour. But your maintenance and repair costs as machine gets older it is increasing. Similarly, downtime cost is increasing and your obsolescence cost is increasing with increasing age of the machine. Now, when you add all the total costs, what is the trend we will see?

So, for the first year the cost is high 855.79. Now, the cost is reducing 851.79 for the second year, now still reducing 849.24 for the third year, for the 4th year it is minimum. Now, again what is happening cost starts increasing again? From 844 it is increasing to 849. So, you can see that you are getting a trend like a parabola. Initially the cost is high then the cost reduces it reaches a minimum point then again it starts increasing, why it starts increasing you know that, because the increase in the age of the machine your maintenance and repair costs is increasing, downtime cost is increasing, your obsolescence cost is increasing.

So, there is an increase in the cost of machine after a particular point, significant increase you can see. So, beyond 4th year your cost is increasing. So, now the economic life means the period during which the cost associated with the machine is minimum, that is it economic life. So, during the 4th year the cost is minimum. So, at the end 4th year it is advisable to replace your machine.

So, the economical life of the machine is 4th year, because the minimum cost is 844.31. So, the equipment owner will not prefer to hold the machine when cost associated with the machine is going to be high. So, beyond the 4th year it is increasing. So, at the end of 4th year, it is better to replace old machine with a new machine. So, if you are not going to replace the old machine with a new machine, if you are still going to hold it for 1 more year say 5th year.

So, this difference will be the loss, this 849.19 minus 844.31. So, this difference is going to be your loss. So, this loss per hour, it will be reflected for the entire 5 years. So, the loss per hour is going to be reflected for the entire 5 years, that is what is the main thing when we do it on the cumulative basis. So, I hope you understand. So, this loss is not reflected, not just in the past 1 year, loss per hour is going to be reflected in the entire 5 years of the machine.

If you are going to retain the machine for 5 years, even beyond the optimum replacement time of the 4th year, if you continue use of the machine for more years, beyond the optimum replacement time the loss is reflected in every operating hour till you the hold the machine. So, that we have noted. So, this is how we estimate the economic life of the machine. So here we have optimized the productivity with respect to cost.

That is why we are going with minimum cost approach. If you are going to optimize the productivity with respect to profit, then you have to go for maximum profit approach. You have to find the time period during which the profit is maximum. So, even that approach we will be discussing in the next lecture.

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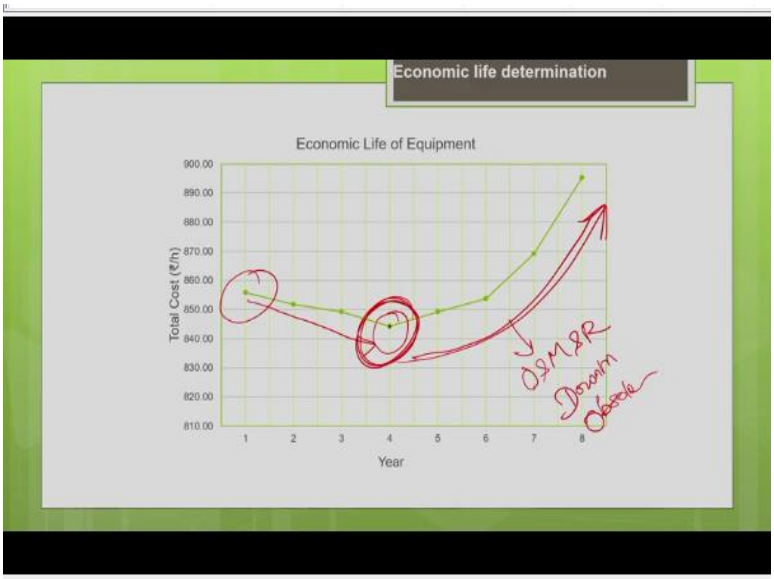


So, this picture, it just shows you the pictorial representation what I discussed in the earlier slide. So, during the initial period, you can see that the cost associated with the machine is slightly high, then the cost starts reducing as the cost is distributed over a greater period, it starts reducing. Now it reaches a minimum point and after that it starts significantly increasing, why this significant increase?

It is mainly due to the increase in the operating costs or the maintenance and the repair cost, your downtime cost, your obsolescence cost, everything is increasing significantly, that is why you can see there is a significant increase in costs with increasing age of the machine. It is better to replace the machine at the end of the 4th year. So, the economic life for this machine is 4th year.

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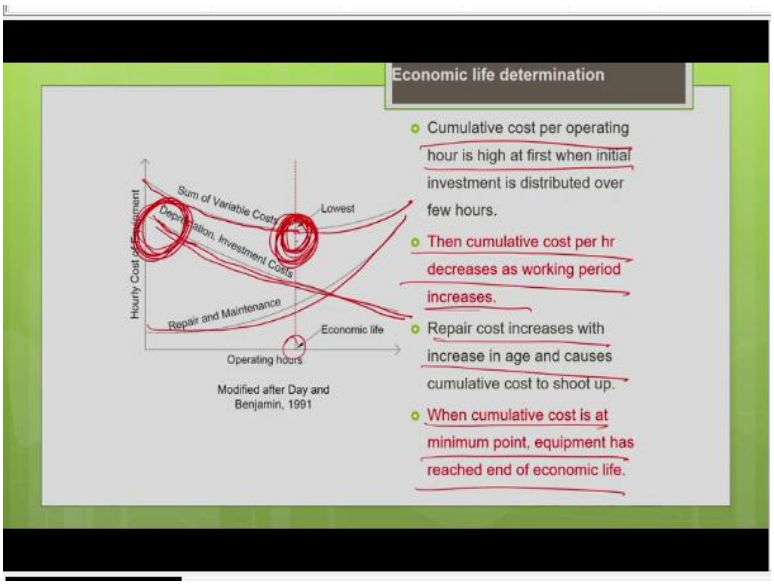


So, this picture shows you are the breakup of all the costs trend. So, we are finding the variation between the costs of the machine with the usage of machine. So obviously your depreciation, your investment costs, all your ownership cost is decreasing with the time. As I told you earlier, as these costs are getting distributed over greater usage, over greater hours, the cost per hour is getting reduced.

So, your repair and the maintenance cost, as the machine gets older, you can see that the cost starts increasing significantly. Similarly, when you add both, this is your ownership cost. This is your operating cost, when you add both you get your total cost, this is your total cost. So, if you see the total cost curves, initially it is high, it reduces, reaches a minimum point then again starts increasing.

So, this is your economic point, minimum point, this is the economic life of the machine, you are supposed to replace the machine at the end of this time. So, that is what is explained here, the cumulative cost per operating hour is high at the first, when the initial investment is distributed over a few hours. So, you can see that the initial investment it is distributed over a few hours, the cost is high.

So, then as the cumulative cost per hour decreases, as the working period increases, as the working period increases, you can see the cumulative cost is decreasing. So, the repair cost increases, with

increasing age, it is increasing with increasing age. So, when the cumulative cost is minimum point, it means the equipment has reached the end of the economic life. So, it has reached a minimum point here. So, this is your economic life. So, this is optimum replacement time for your machine.

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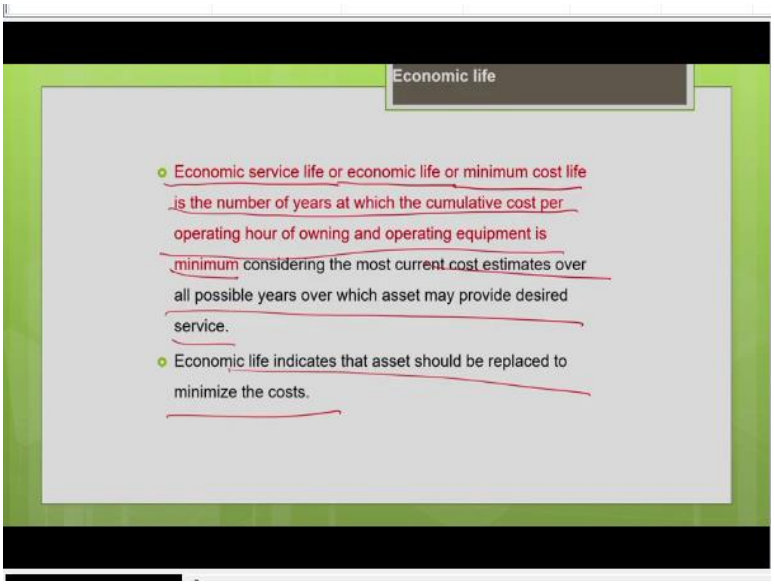


So, what is economic life? There are different terminologies used, we can call it as economic service life or economic life or minimum cost life. So, this is the number of years at which the cumulative cost per operating hour of the owning and operating equipment is minimum. Considering the most current costs estimates over all the possible years, over which the asset may provide desired service.

As I told you, you should consider all the components associated with the cost, so that we can make an accurate estimation of the replacement time of the machine. So, the economic life indicates that the asset should be replaced to minimize the cost associated with the machine.

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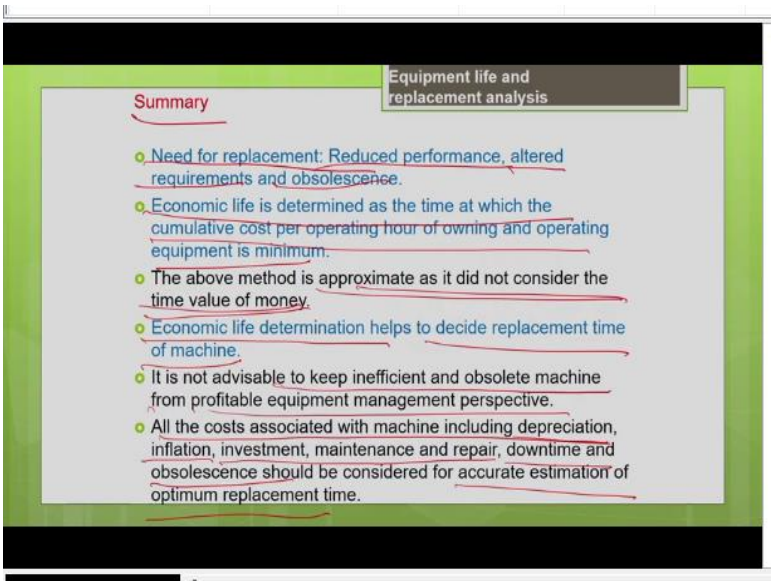


So, we have come to the end of this lecture 6. So, let me summarize what I have discussed so far. So, basically, we know the need for replacement of the machine. So, why should we replace the old machine with a new machine? Because your old machine because of the wear and tear, it may be showing reduced performance, reduced productivity and there may be a sudden increment in your productivity requirement in your project site.

So, there may be some altered requirement, you may face some increment in the production requirement. So, for that you have to replace the old machine with a new machine, which has a better productivity than your old machine. And obviously, your machine would have become obsolete because of many competitive models available in the market. So, there are different reasons which justifies the replacement of the old machines with a new machine.

So, economic life is a time at which your cumulative costs per operating hour of the machine is minimal. So, that is what we have discussed. And one thing we have to note here, though, we consider most of the costs associated with your machine, but one thing what we have missed in the previous analysis is we did not consider the time value of money. When you do not consider the time value for money, obviously, your cost estimate or the decision is going to be only approximate.

So, as we discussed earlier lectures, we should consider the timing of the cash flows and convert all the cash flows, which are occurring at different time interval into equal cash flows at a particular time period and make a rational comparison. So, that only it gives you an accurate estimate. So, this method we are going to do in the upcoming lecture. So, to get an accurate estimate, we have to consider the timing of the cash flows.

So, the main objective of determining the economic life is to decide the optimum replacement time of the machine. It is not advisable to keep inefficient and obsolete the machine, even though your machine may be functioning at your project site. It is not totally broken down even though it is functioning it is not advisable to just continue with the usage of old machine. So, from profitable equipment management perspective, we should not just cling on to the old machine, when its productivity is less.

We should see for the optimum replacement time and replace it with a newer productivity model, newer model which is available in the market with a better productivity. So, for the equipment replacement analysis, we are supposed to consider all the costs as I mentioned earlier, include the depreciation cost, effect of inflation, investment costs, maintenance and repair downtime, obsolescence, everything should be considered for the accurate estimation of the optimum replacement time.

So, these are the points we should keep in mind when you do the replacement analysis. So, these are the references, these are textbooks which I recommend for the preparation related to this topic.
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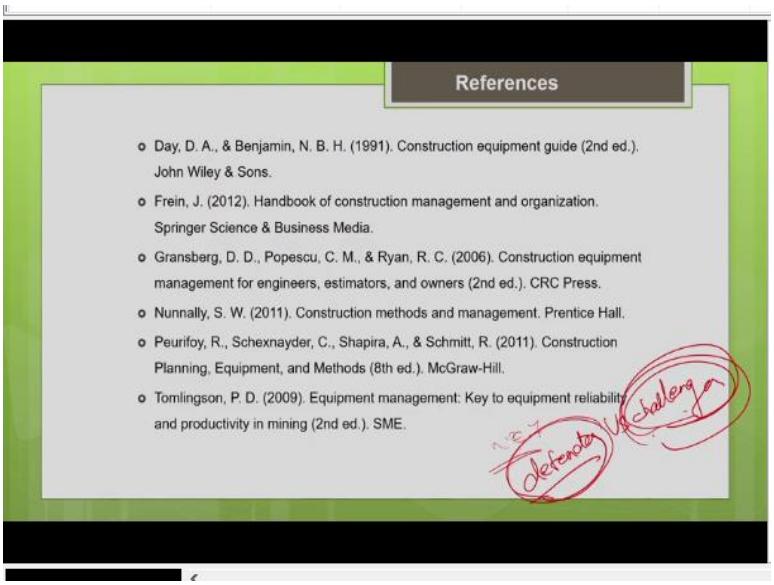


So, basically in the lecture 7 in the upcoming lecture, I will be discussing on the equipment replacement analysis. So, we will be discussing some more different approaches like how to compare the defender and challenger. So, hope you remember what is defender and challenger, defender is a current machine, what which are the processing of your site and challenger is your proposed machine which are planning for replacement. So, now we have determined what is the optimum replacement time for the current machine?

Now, you have to see what is the best alternative available for the replacement? Whether the challenger is suitable for replacement or not that we have to compare. So, by comparing the cost of defender and the challenger, we will decide whether the challenger is suitable for replacement or not and you will also see what is the optimum replacement of the defender with the challenger. So, other different approaches under replacement analysis will be discussed in the upcoming lecture. Thank you.